



January 30, 2018

Testimony before the House Armed Services Committee

Readying the U.S. Military for Future Warfare

Paul Scharre, Senior Fellow and Director
Technology and National Security
Center for a New American Security

Chairman Thornberry, Ranking Member Smith, and distinguished members, thank you for inviting me to testify today.

The title of today's hearing is readying the U.S. military for future war. I regret to say that the U.S. military is not ready for the threats we face today.

In a recent simulation of a war in the Western Pacific, colleagues of mine at the Center for a New American Security showed that a Chinese missile strike on U.S. bases in the region could destroy more than 200 aircraft on the ground, crater every runway at U.S. airbases in Japan, hit almost every major headquarters within minutes of a conflict starting, destroy key logistical facilities, and hit almost every U.S. ship in port in Japan.¹

This is not a new problem. Similar analyses done by other defense experts have consistently shown that the United States' ability to project power into the Western Pacific has been steadily declining. China's arsenal of hundreds of cruise missiles and over 1,000 ballistic missiles poses a significant threat to U.S. bases in the region and aircraft carriers. The U.S. military faces similar problems in Europe, where the United States has fallen behind Russian investments in long-range precision strike, integrated air defenses, and electronic warfare.

These problems did not spring up overnight. Broadly categorized under the label of anti-access capabilities, these threats to U.S. power projection are well understood. Defense analysts have been warning about the U.S. military's waning ability to project power into contested regions for the past two decades. And these threats have been recognized in every official DOD strategy document since the 2001 Quadrennial Defense Review. Moreover, the steps necessary to counter these threats are clear – increased investment in: long-range strike, stealthy uninhabited aircraft to hunt for mobile targets, advanced munitions, electronic warfare, and undersea strike.

Bold.

Innovative.

Bipartisan.

Yet the military has made only halting steps towards these investments. The Air Force is still heavily weighted towards short-range tactical fighter aircraft and, under current plans, will remain so for decades to come. The Navy's aircraft carriers similarly only carry short-range fighters, limiting the carrier's usefulness in the early stages of a major conflict. Despite strong pressure from Congress, the Navy has no plans to invest in a long-range strike aircraft to extend the carrier's reach. The Army has even more acute problems in power projection due to the reduction in Army brigades forward based in Europe and the complete lack of any effective Army modernization for the past fifteen years.

Why are we here? We spend more money than our adversaries. The United States is a global technology leader. And our warfighters are better educated, trained, and motivated than our adversaries. We have seen this problem coming for two decades, yet we have failed to adequately respond.

It is not for a lack of money. With sufficient reforms, there is ample money within a \$600 billion defense budget. Budgetary stability is necessary. The current budgetary instability inflicted on the military due to a failure of the nation's political leaders to reach a bipartisan deal on taxes and entitlements has severely hampered readiness and modernization. We cannot field a first-class military through government shut downs, continuing resolutions, and constant uncertainty about long-term spending.² But these problems predate the current budgetary crises. Money alone will not cure what ails the Pentagon.

Nor is it because the Pentagon has been fixated on wars in the Middle East. From 2001 to 2008, the base budgets of the Navy and Air Force grew 22% and 27%, respectively, in real dollars. At the same time, the number of combat ships declined by 10% and combat aircraft by 20% over that same period.³ The Army squandered over \$18 billion on its Future Combat Systems program, with little to show for it. On top of that, the Pentagon wasted an additional \$25 billion on other failed modernization initiatives in the early 2000s.⁴ Taxpayer money – a lot of it – went towards military modernization for future threats, even while troops were fighting in Iraq and Afghanistan.

The reason we have failed to adapt is because our system lacks sufficient strategic agility. We have seen these threats coming a long ways off. We have spent money. Yet we have a force that is not appropriately designed for the threats we face because we have not adapted quickly enough.

There are three main obstacles to more rapid adaptation: a ponderous and risk-averse acquisition system; stickiness in our programs that makes it difficult to cancel legacy systems less suited to future needs; and cultural resistance within elements of the military to new paradigms of warfighting.

The need for acquisition reform is well-understood in defense circles. Reform can mean many different things, however, and some goals for reform may be at odds with others. For example, reforms aimed at reducing wasteful spending – a valuable goal – could end up adding red tape and slowing down an already sluggish process. If the U.S. military is to be more adaptable, then the primary goal of acquisition reform should be speed. The DOD must accelerate the pace of requirements and acquisitions.

DOD has some experience with rapid fielding. During the wars in Iraq and Afghanistan, DOD accelerated the acquisition of vital capabilities – body armor, counter-improvised explosive device (IED) technology, mine-resistant ambush protected (MRAP) vehicles, and intelligence, surveillance and reconnaissance (ISR) assets. Unfortunately, to do so senior defense leaders were forced to go around the standard requirements and acquisition processes, rather than work within it. To field combat capabilities in a relevant timeframe, senior leaders had to create standalone ad hoc organizations: the Rapid Equipping Force (REF), Joint IED Defeat Organization (JIEDDO), Joint Rapid Acquisition Cell (JRAC), MRAP Task Force, and ISR Task Force, among others.

These organizational initiatives are often held up as examples of successful innovation, and while individually they are success stories, it is worth putting their creation in context. During two of America's longest wars, the DOD's standard methods for fielding new equipment were too slow to be useful. Even worse, senior leaders were not effective in creating a generalized rapid process, despite efforts to do so. Rather, for each new capability, senior leaders had to create purpose-built organizations that reported directly to senior leaders so that they would not be stymied by other parts of the bureaucracy. This is not the hallmark of an agile system.

Even when innovation occurred, it often came late to need. Urgent requests from combat units in Iraq for MRAPs languished in the halls of the Pentagon for two years before Secretary of Defense Robert Gates became personally involved and directed MRAP procurement. And this was in spite of intense pressure from Congress, including this committee, to urgently field MRAPs. The cost to this delay was hundreds and possibly thousands of servicemembers' lives.⁵ In a major war, the cost could be even greater. For perspective, the three years it took the Pentagon to field MRAPs corresponds to nearly all of U.S. involvement in World War II. If the request had been submitted on the day after Pearl Harbor, units would not have arrived in significant numbers until the final six months of the war.

In a major power war, we will be required to innovate on timelines of months, not years. And we must have these processes of innovation in place today. DOD has taken steps to institutionalize some of the rapid innovation processes used in Iraq and Afghanistan and has created new organizations, such as the Strategic Capabilities Office (SCO). These organizations are valuable, but we must also make speed-to-market a goal in our standard acquisition process as well. At present, it can take decades to bring a new major weapon system to fruition. This process is too slow, and often the security environment evolves in the intervening years to make systems less valuable. In short, reality is operating inside our bureaucratic OODA loop.¹

The DOD needs to acquire major weapons systems on shorter timelines. Perhaps counter-intuitively, this means that the best strategy for preparing for future wars is to eschew ambitious “leap ahead” transformational programs and instead orient modernization initiatives to what is achievable in the near-term with existing technology. DOD should invest in emerging technologies, but prototyping and experimentation should be separate from acquisition. DOD should not embark down the path of procuring a new major weapon system until the technology is mature.

¹ The “OODA loop” comes from a paradigm for combat in which the winning competitor is the one who completes a cognitive process – observe, orient, decide, act (OODA) – faster than his or her adversary.

The slowness of our acquisition system is unfortunately compounded by political and bureaucratic structures in the Pentagon, defense industry, and Congress that make it exceedingly difficult to cancel or curtail programs that are less useful. Defense secretaries who seek to reorient the DOD to future threats face an uphill battle against their own subordinates, industry, and too often members of Congress who seek to defend existing programs. Existing programs are “sticky” – they have advocates throughout the defense enterprise. There are fewer institutional advocates for new programs: no program office in the Pentagon to defend their goals, no money to defend contractors, and no jobs in members’ districts. This asymmetric incentive structure is baked into our process and there is no easy fix other than strong leadership. If DOD is to be adaptable, Congress must be a willing partner in cancelling or curtailing programs that are no longer best suited for future wars.

Finally, in some cases, cultural resistance to new paradigms for warfighting can be a hindrance to some kinds of innovation. Many forms of innovation fall within existing paradigms for warfighting and are easily embraced by military communities – for example, longer-range missiles or more maneuverable fighters. Some kinds of military innovations, however, require major paradigm shifts in combat, such as the transition from horses to tanks. These shifts are often met by resistance from military communities, in spite of the fact that these innovations would lead to combat advantage. Unfortunately, this is the case for some kinds of innovation today.

The Air Force and Navy aviation community have both been extremely reluctant to adopt uninhabited combat aircraft. The Air Force has embraced uninhabited aircraft for reconnaissance missions, but not combat missions. The Navy is investing in an uninhabited carrier-based aircraft for tanking, but not strike missions. This is consistent with a pattern across the military services of using uninhabited and robotic systems in support roles, but not combat roles, even when they have clear advantages. In the case of airpower, uninhabited aircraft are essential for power projection into contested areas because of their greater endurance than human-inhabited aircraft. With refueling, uninhabited aircraft could stay aloft for 10 to 20 hours or more, far longer than what is possible with a human in a single-seat aircraft. These advantages were first recognized over a decade ago in the 2006 Quadrennial Defense Review, which directed the Navy to: “develop an unmanned longer-range carrier-based aircraft capable of being air-refueled to provide greater standoff capability, to expand payload and launch options, and to increase naval reach and persistence.”⁶ Despite intense pressure from Congress and impressive technological progress in the form of the X-47B demonstration aircraft, these goals remain unfulfilled. The Navy’s current carrier-based uninhabited aircraft program the MQ-25, is oriented towards aerial refueling,⁷ and the Navy has no program underway to develop a penetrating strike aircraft. This gap means that aircraft carriers, a visible symbol of American power and a significant financial investment, will be of reduced value in the early stages of a conflict against major competitors, when they are most needed.

More generally, rebalancing the military to project power in the face of anti-access threats requires a fundamental re-look at the balance of investments within the Navy and Air Force. The vast bulk of the Air Force’s combat fleet consists of short-range tactical fighters. Unfortunately, these will also be of little utility in the early stages of a high-end conflict, when adversary ballistic missiles will hammer U.S. air bases. The Air Force needs to extend its reach. The B-21 bomber is a key capability for doing so, and Congress should work with the DOD to ensure that once the bomber enters production, it is procured at the maximum rate of production. The B-21 must also be augmented

with stealthy uninhabited aircraft to provide persistent surveillance and strike capability against mobile and relocatable targets such as missile launchers and radars. Congressional leadership is needed to help ensure DOD is maximizing its opportunities in this area as well. Over time, the Air Force needs to shift its investment profile away from short-range fighters to longer-range aircraft, or else DOD will face a long-term horizon of waning airpower and combat effectiveness.

For the Navy, acquisition of a stealthy uninhabited penetrating strike aircraft is essential to keeping the aircraft carrier relevant in the face of longer-range ballistic and cruise missiles. Even with this capability, though, the proliferation of precision-strike suggests a fundamental re-examination of the balance of investments across the three components of American sea power: surface ships, carriers, and submarines. Today, the United States has an unparalleled advantage in undersea warfare capabilities. The United States is able to use the undersea environment as a sanctuary and operate deep within adversary anti-access regions and strike enemy targets from undersea. The Navy should capitalize on this opportunity, expanding Virginia-class submarine production. The Navy should also invest in uninhabited undersea vehicles (UUVs) and undersea payload modules to expand sensor and strike capacity.

The Army and Marine Corps are culturally in a better place, as the transition away from long-duration counterinsurgency wars towards more traditional threats is more within their comfort zone. Nevertheless, they face challenges as well. The Army has similarly been slow to embrace ground robotic vehicles, particularly armed systems, in spite of significant Russian investment in armed ground robots.⁸ The Army also must overcome a strong anti-technology strain of thinking, a product partly of the failure of technological advantage to yield meaningful strategic outcomes in Iraq and Afghanistan.⁹ For the Marine Corps, anti-access threats pose serious challenges to current amphibious warfare tactics, and the Marine Corps must evolve new technologies and concepts for amphibious assault and forcible entry.

The United States military is capable of adapting to these future challenges. U.S. warfighters can generate creative solutions to operational problems, and the U.S. industrial base is capable of fielding unparalleled military capabilities. The most difficult challenge is focusing defense institutions on the right problems and holding the military services accountable for developing solutions. Power projection in the face of anti-access threats is a major problem for the U.S. military today, and Congressional leadership will be essential in ensuring that the military reorients its forces to develop effective solutions.

Priority Investment Areas

Listed below are priority investment areas for modernizing the U.S. military to meet future threats.

Air power

- **Long-range penetrating strike aircraft** – Maximize the rate of procurement for the B-21 bomber once it goes into production.
- **Persistent surveillance and strike aircraft** – Develop a stealthy uninhabited combat air vehicle (UCAV) to persist inside enemy territory to hunt mobile and relocatable targets.

- **Robust, secure networks** – Build an aerial layer network for resilient communications and position, navigation, and timing (PNT) in the event of disruption of space assets.
- **Next-generation weapons** – Increase quantities of the Joint Air-to-Surface Standoff Missile–Extended Range (JASSM-ER) and Long-Range Anti-Ship Missile (LRASM), and develop a new longer-range air-to-air missile.
- **Air-launched swarming drones** – Field small air-launched swarming air vehicles for jamming, decoys, reconnaissance, battle damage assessment, and strike.
- **Low-cost delivery systems** – Maximize the use of existing aircraft (e.g., B-1, B-52, F-15, F-16, and MQ-9) and consider new, low-cost air vehicles to act as delivery systems for standoff weapons, decoys, and air-launched swarms.
- **Light attack aircraft** – Field a low-cost, light attack aircraft for counter-terrorism, close air support, and other missions in permissive air environments.
- **Artificial intelligence** – Leverage artificial intelligence and data analytics to help process large volumes of data and cue items of interest to human analysts.
- **Emerging technologies** – Invest in and mature key emerging technologies such as artificial intelligence, autonomy, and directed energy weapons.

Sea power

- **Carrier aviation** – Develop a stealthy, uninhabited combat air vehicle (UCAV) to extend the reach of aircraft carriers in contested environments.
- **Submarines** – Increase the rate of Virginia-class submarine production to capitalize on the United States’ undersea advantages.
- **Undersea** – Procure large-diameter uninhabited undersea vehicles (UUVs), both submarine-delivered and ship-delivered, to augment undersea capabilities. Experiment with undersea payload modules as low-cost means of augmenting undersea payload capacity.
- **Lower-cost expeditionary ships** – Invest in commercial-derivative (“black hull”) expeditionary sea bases for more cost-effective expeditionary operations.
- **Robotics** – Field low-cost uninhabited surface vessels for anti-submarine warfare and to act as additional missile batteries to augment destroyers.
- **Missile defense** – Invest in hyper velocity projectiles and mature electromagnetic rail gun technology to improve ship defenses against ballistic and cruise missiles.
- **Protection** – Invest in armed uninhabited surface vessels (USVs) to act as escort and interdiction ships for high-value assets against potential threats in high-threat areas, such as during strait transit. Equip surface ships’ small boats with robotic applique kits to allow them to operate “optionally manned” for use as uninhabited interdiction boats against potential threats.

Land power

- **Armor** – Increase the number of active duty armored brigade combat teams (BCTs).
- **Survivability** – Upgrade ground vehicles with active protection systems (APS) to intercept precision-guided anti-armor weapons.
- **Fires** – Increase the range, capacity, and lethality of long-range precision fires.
- **Communications and electronic warfare** – Invest in protected communications, electronic warfare, and electromagnetic decoys to ensure forces are survivable and can communicate in contested electromagnetic environments.
- **Air defenses** – Invest in short-range air defenses to protect ground forces from air attack.
- **Missile defense** – Upgrade Paladin 155mm howitzers with hyper velocity projectiles (HVPs) and targeting capabilities for ballistic and cruise missile defense.¹⁰
- **Robotics** – Experiment with new operational concepts leveraging air and ground robotic teammates.
- **Lethality** – Mature and field advanced precision-guided weapons for dismounted troops, such as counter defilade weapons and smart rifles.
- **Mobility** – Mature exoskeleton and exosuit technologies to improve individual mobility and protection.
- **Protection** – Increase troop protection against blast-induced brain injury through improved helmet design.
- **Human performance** – Research the benefits and risks of human enhancement technologies, such as transcranial direct current stimulation (tDCS)¹¹ and pharmaceutical enhancements to improve alertness and cognitive performance, such as modafinil.¹² Establish a DOD-wide process for integrating these technologies and techniques into the force in a safe and ethical manner.

Recommendations for Further Reading

Susanna V. Blume and Lauren Fish, “A Brief History of Defense Budget Instability,” November 8, 2017, <https://www.cnas.org/publications/reports/a-brief-history-of-defense-budget-instability>.

Eric Heginbotham et al., “The U.S.-China Military Scorecard,” The RAND Corporation, 2015, <https://www.rand.org/paf/projects/us-china-scorecard.html>.

Jerry Hendrix, Paul Scharre, and Elbridge Colby, “Why America Must Overhaul its Military,” *The National Interest*, October 19, 2016, <http://nationalinterest.org/blog/the-buzz/why-america-must-overhaul-its-military-18096>.

David Ochmanek, “Recommendations for a Future National Defense Strategy,” Testimony before the Senate Armed Services Committee, November 30, 2017, <https://www.rand.org/pubs/testimonies/CT484.html>.

David Ochmanek et al., “U.S. Military Capabilities and Forces for a Dangerous World,” The RAND Corporation, 2017, https://www.rand.org/pubs/research_reports/RR1782.html.

Paul Scharre, “Future of All Arms Warfare in the 21st Century,” Testimony before the Subcommittee on Airland of the Senate Armed Services Committee, March 15, 2017, <https://www.cnas.org/publications/congressional-testimony/paul-scharre-before-the-subcommittee-on-airland-of-the-senate-armed-services-committee>.

Paul Scharre, “Future of Warfare,” Testimony before the Senate Armed Services Committee, November 3, 2015, <https://www.cnas.org/publications/congressional-testimony/paul-scharre-testimony-before-sasc1>.

Paul Scharre, “Making Sense of Rapid Technological Change,” Center for a New American Security, July 19, 2017, <https://www.cnas.org/publications/commentary/making-sense-of-rapid-technological-change>.

Paul Scharre, “Robotics on the Battlefield Part II: The Coming Swarm,” Center for a New American Security, October 2014, 16, <https://www.cnas.org/publications/reports/robotics-on-the-battlefield-part-ii-the-coming-swarm>.

Thomas Shugart and Javier Gonzalez, “First Strike: China’s Missile Threat to U.S. Bases in Asia,” Center for a New American Security, June 2017, <https://www.cnas.org/publications/reports/first-strike-chinas-missile-threat-to-u-s-bases-to-asia>.

CNAS Funding

CNAS is a national security research and policy institution committed to the highest standards of organizational, intellectual, and personal integrity. The Center retains sole editorial control over its ideas, projects, and productions, and the content of its publications reflects only the views of their authors. In keeping with its mission and values, CNAS does not engage in lobbying activity and complies fully with all applicable federal, state, and local laws. Accordingly, CNAS will not engage in any representation or advocacy on behalf of any entities or interests and, to the extent that the Center accepts funding from foreign sources, its activities will be limited to bona fide scholastic, academic, and research-related activities, consistent with applicable federal law. A full list of CNAS supporters and the center's funding guidelines can be found here: <https://www.cnas.org/support-cnas>.

Consistent with Rule 11, clause 2(g)(5), of the Rules of the U.S. House of Representatives for the 115th Congress, a detailed list of CNAS federal contracts or grants (including subcontracts and subgrants), or contracts or payments originating with a foreign government, received during the current and two previous calendar years has been provided to this committee as an attachment.



PAUL SCHARRE is a Senior Fellow and Director of the Technology and National Security Program at the Center for a New American Security. He is author of the forthcoming book, [*Army of None: Autonomous Weapons and the Future of War*](#), to be published in April 2018.

From 2008-2013, Mr. Scharre worked in the Office of the Secretary of Defense (OSD) where he played a leading role in establishing policies on unmanned and autonomous systems and emerging weapons technologies. Mr. Scharre led the DoD working group that drafted DoD Directive 3000.09, establishing the Department's policies on autonomy in weapon systems. Mr. Scharre also led DoD efforts to establish policies on intelligence, surveillance, and reconnaissance (ISR) programs and directed energy technologies. Mr.

Scharre was involved in the drafting of policy guidance in the *2012 Defense Strategic Guidance*, *2010 Quadrennial Defense Review*, and Secretary-level planning guidance. His most recent position was Special Assistant to the Under Secretary of Defense for Policy.

Prior to joining OSD, Mr. Scharre served as a special operations reconnaissance team leader in the Army's 3rd Ranger Battalion and completed multiple tours to Iraq and Afghanistan. He is a graduate of the Army's Airborne, Ranger, and Sniper Schools and Honor Graduate of the 75th Ranger Regiment's Ranger Indoctrination Program.

Mr. Scharre has published articles in the *New York Times*, *Foreign Policy*, *Politico*, *Proceedings*, *Armed Forces Journal*, *Joint Force Quarterly*, *Military Review*, and in academic technical journals. He has presented at the United Nations, NATO Defence College, Chatham House, National Defense University and numerous other defense-related conferences on robotics and autonomous systems, defense institution building, ISR, hybrid warfare, and the Iraq war. He has appeared as a commentator on CNN, MSNBC, NPR, the BBC, and Swiss and Canadian television. Mr. Scharre is a term member of the Council on Foreign Relations. He holds an M.A. in Political Economy and Public Policy and a B.S. in Physics, cum laude, both from Washington University in St. Louis.

Notes

- ¹ Thomas Shugart and Javier Gonzalez, “First Strike: China’s Missile Threat to U.S. Bases in Asia,” Center for a New American Security, June 2017, <https://www.cnas.org/publications/reports/first-strike-chinas-missile-threat-to-u-s-bases-to-asia>.
- ² Susanna V. Blume and Lauren Fish, “A Brief History of Defense Budget Instability,” Center for a New American Security, November 8, 2017, <https://www.cnas.org/publications/reports/a-brief-history-of-defense-budget-instability>.
- ³ Paul Scharre, “Robotics on the Battlefield Part II: The Coming Swarm,” Center for a New American Security, October 2014, 16, <https://www.cnas.org/publications/reports/robotics-on-the-battlefield-part-ii-the-coming-swarm>.
- ⁴ Todd Harrison, “Analysis of the FY 2012 Defense Budget,” Center for Strategic and Budgetary Assessments, viii.
- ⁵ Christopher J. Lamb, Matthew J. Schmidt, and Berit G. Fitzsimmons, “MRAPs, Irregular Warfare, and Pentagon Reform,” Institute for National Strategic Studies, June 2009.
- ⁶ Department of Defense, “Quadrennial Defense Review Report,” February 6, 2006, 46.
- ⁷ Naval Air Systems Command, “MQ-25 UAS,” <http://www.navair.navy.mil/index.cfm?fuseaction=home.display&key=A1DA3766-1A6D-4AEA-B462-F91FE43181AF>.
- ⁸ Samuel Bendett, “Russia is Poised to Surprise the U.S. in Battlefield Robotics,” *Defense One*, January 25, 2018, <http://www.defenseone.com/ideas/2018/01/russia-poised-surprise-us-battlefield-robotics/145439/>.
- ⁹ H.R. McMaster, “The Pipe Dream of Easy War,” *New York Times*, July 20, 2013, <http://www.nytimes.com/2013/07/21/opinion/sunday/the-pipe-dream-of-easy-war.html>.
- ¹⁰ Sam LaGrone, “Pentagon: New Rounds for Old Guns Could Change Missile Defense for Navy, Army,” USNI News, July 18, 2016.
- ¹¹ Jeremy Nelson, R. Andy McKinley, Edward Golob, Joel Warm, and Raja Parasuraman, “Enhancing vigilance in operators with prefrontal cortex transcranial direct stimulation (tDCS)” *NeuroImage* 85 no. 3 (January 2014), 909-917. Justin Nelson, Richard McKinley, Chandler Phillips, Lindsey McIntire, Chuck Goodyear, Aerial Kreiner, and Lanie Monforton, “The Effects of Transcranial Direct Current Stimulation (tDCS) on Multitasking Throughput Capacity, *Frontiers in Human Neuroscience*, (2016).
- ¹² Arthur Estrada et al., “A comparison of the efficacy of modafinil and dextroamphetamine as alertness promoting agents in aviators performing extended operations,” *United States Army Aeromedical Research Laboratory*, Report No. 2011-05, December 2010, 4. Amanda Kelley et al., “Cognition-enhancing drugs and their appropriateness for aviation and ground troops: a meta-analysis,” *United States Army Aeromedical Research Laboratory*, Report No. 2011-06, December 2010, 4. Amanda Kelley, Catherine Webb, Jeremy Athy, Sanita Ley, and Steven Gaydos, “Cognition enhancement by modafinil: a meta-analysis.” *Aviation, Space, and Environmental Medicine*, 83 no. 7 (July 2012), 685-690.